

# (12) UK Patent Application (19) GB (11) 2 317 506 (13) A

(43) Date of A Publication 25.03.1998

(21) Application No 9720098.4

(22) Date of Filing 23.09.1997

(30) Priority Data

(31) 9619849

(32) 24.09.1996

(33) GB

9710445

22.05.1997

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(51) INT CL<sup>6</sup>

H02K 44/04

(52) UK CL (Edition P)

H2A AKS4 AKX2B AK124 AK213S AK214B AK217S  
AK807

(56) Documents Cited

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(58) Field of Search

UK CL (Edition O) H2A AKS4

INT CL<sup>6</sup> H02K 44/04

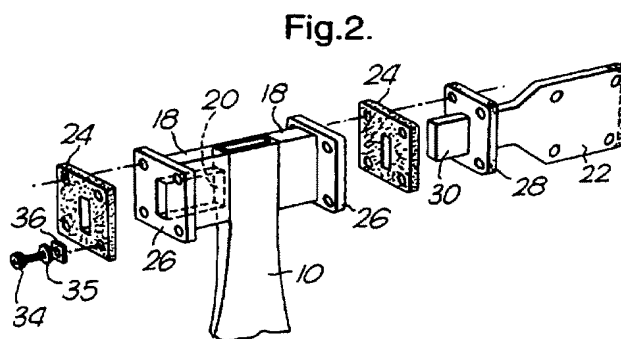
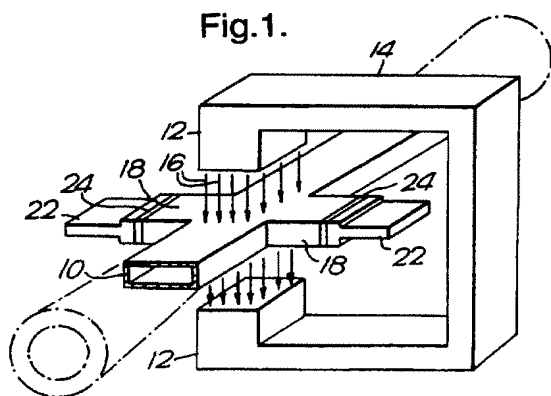
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## (54) Liquid metal pump having insulated demountable electrodes

(57) A liquid metal pump (5) includes a flow duct (10) which passes through the magnetic field (16) of a magnet (14), with two electrodes (22) locating in apertures in the duct walls directly opposite each other. The demountable electrodes (22) are electrically insulated from the walls of the duct (10) by gaskets (24), and are supported by flanged side ducts (18). A voltage applied between the electrodes (22) causes an electric current to flow through the liquid metal, and the interaction with the field (16) causes the liquid metal to flow.



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Fig. 1.

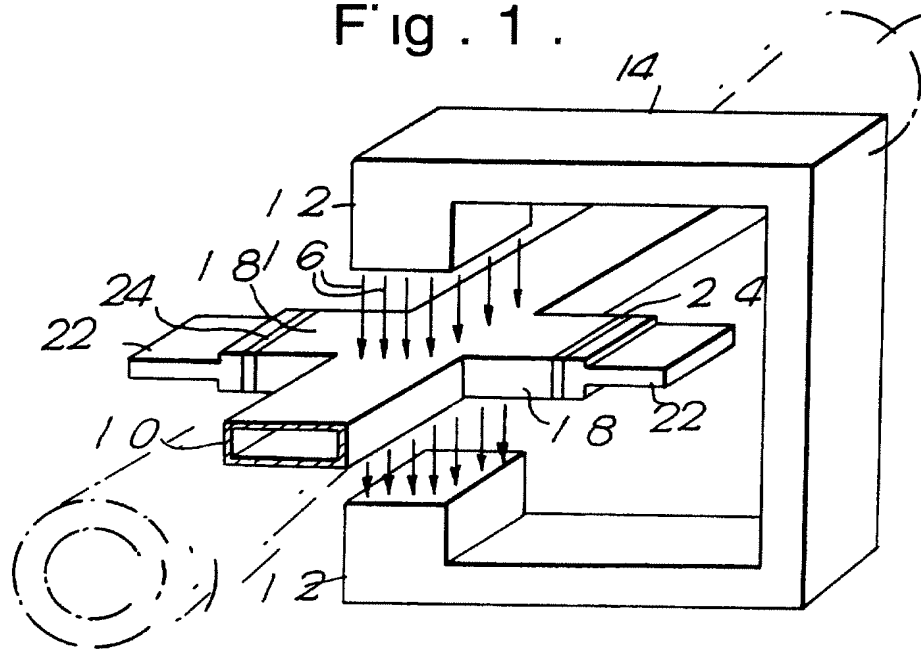
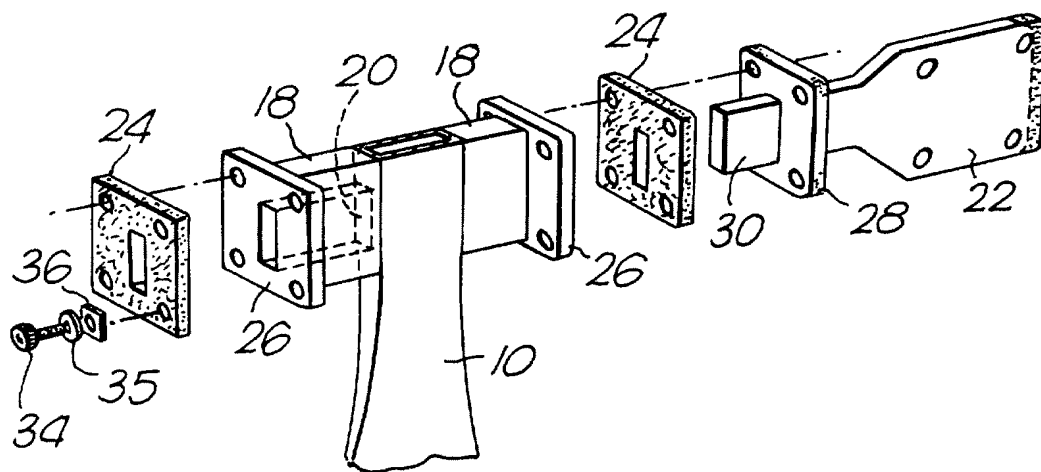


Fig. 2.



Liquid Metal Pump

The invention relates to a pump for pumping liquid metal, and to the use of such a pump, particularly but  
5 not exclusively for pumping molten solder.

A known technique for pumping a liquid metal such as mercury or molten sodium uses a duct, which may be of a metal alloy, passing between the poles of a magnet. An  
10 electric current is passed between opposed electrodes on the walls of the duct so as to flow through the metal at right angles to the magnetic field, and so cause the metal to flow. For example GB 567 772 describes a mercury pump with a duct of nickel-chromium alloy, with  
15 electrodes of nickel or iron brazed to the duct in slots opposite each other, or fixed to the duct by vitreous enamel. GB 914 908 describes a pump used for mercury, sodium or potassium, with a duct of high resistance metal, with electrodes either inserted into and sealed to  
20 opposite walls or electrically joined to the outer surfaces of those walls. Problems have been found to arise when applying this technique to other liquid metals such as molten solder, not only in ensuring sufficient electric current flows through the molten metal rather  
25 than the duct wall, but because an insulating layer gradually builds up on the wall or electrode surfaces. To some extent these problems can be overcome by coating the electrode surface with a more readily wetted material, but in the long term such coatings may dissolve in the  
30 molten metal.

According to the present invention there is provided a pump for pumping a liquid metal, the pump comprising a duct which in operation contains said liquid metal, the  
35 duct extending through a region in which a magnet creates a magnetic field so the longitudinal axis of the duct is

transverse to the magnetic field, two side ducts  
extending transverse to both the axis of the duct and to  
the magnetic field, and communicating with respective  
apertures at opposite sides of the duct, electrodes  
5 locating in the side ducts, demountably connected to them  
and sealed to them by gaskets, and means to apply an  
electric voltage between the electrodes, such that the  
electrodes are electrically insulated from each other in  
the absence of the liquid metal.

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The duct is preferably of non-ferromagnetic  
material, so as to avoid shielding the liquid metal from  
the magnetic field. The preferred material for the duct  
is stainless steel, as this can withstand elevated  
15 temperatures, and does not dissolve in or interact  
chemically with most liquid metals. The side ducts  
preferably have flanges at their ends to which the  
electrodes are connected, the insulating gaskets being  
provided between a flange on the electrode and the end  
20 flange of the side duct. Such gaskets may have to  
withstand elevated temperatures (depending on the nature  
of the liquid metal), and would consequently be made of  
an inert material such as glass fibres.

25 The force exerted on the liquid metal increases with  
the magnetic flux density, and with the magnitude of the  
electric current. The magnet may be a permanent magnet  
or an electromagnet, but in either case it is easier to  
achieve a high flux density if the magnet's poles are not  
30 far apart; evidently they must be far enough apart to  
allow the duct to fit between them. In one embodiment  
the poles might be about 10 mm apart, and about 20 mm  
square, and the duct be of rectangular cross-section in  
the vicinity of the poles; and the electrode faces be  
35 rectangular, about 20 mm by 4 mm, so as to be the same  
length as the region of high flux density, and to have as

large a cross-sectional area as practicable within the size constraints of the space between the poles.

The invention will now be further and more particularly described, by way of example only, and with reference to the accompanying drawings in which:

Figure 1 shows a diagrammatic perspective view of a pump for pumping liquid metal; and

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Figure 2 shows an exploded perspective view illustrating the assembly of the electrodes, some components being omitted for clarity.

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Referring to Figure 1, a pump 5 for pumping liquid metal, such as molten tin or molten solder, comprises a stainless steel duct 10 which passes between the poles 12 of a magnet 14, the duct 10 being of rectangular cross-section in the vicinity of the poles 12 but being circular elsewhere. The separation of the poles 12 is exaggerated for clarity. The magnetic field, indicated by arrows 16, is perpendicular to the longitudinal axis of the duct 10. The part of the duct 10 between the poles 12 has two branch ducts 18 on opposite sides of the duct 10 and also of rectangular cross-section, which communicate with the duct 10 via corresponding rectangular apertures 20 (not shown in Figure 1; see Figure 2). A rectangular electrode 22 locates in each branch duct 18, sealed to the end of the branch duct 18 by an insulating gasket 24, and projects beyond the end of the branch duct 18.

A source of electric current (not shown) is connected between the electrodes 22 in operation, so causing electric current to flow through the liquid metal

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in the duct 10 transverse to both the longitudinal axis of the duct 10 and to the magnetic field 16. This generates a force to drive the liquid metal through the duct 10. The direction of the liquid flow can be  
5 reversed by reversing the direction of the electric current. The current source is a high current low voltage power supply, and by way of example the electrodes 22 might be of cross-section 4 mm by 20 mm, the voltage 0.25 V between the electrodes 22, and the  
10 current 400 A.

Referring to Figure 2 there is shown an exploded perspective view during assembly of the pump 5. As shown in Figure 2 the duct 10 communicates via rectangular  
15 apertures 20 (only one is shown, in broken lines) with two short, stainless steel, branch ducts 18 which are opposite each other. The ends of the branch ducts 18 remote from the duct 10 have rectangular flanges 26. The stainless steel electrodes 22 (only one is shown) consist  
20 of a flat plate with a flange 28 at an intermediate position along its length. The part 30 of the electrode 22 which locates in the branch duct 18 is 0.5 mm clear of the walls of the branch duct 18, and is of such a length that the end face of the electrode 22 is substantially  
25 flush with the inner surface of the wall of the duct 10.

Each electrically insulating gasket 24 locates between the flange 26 and the flange 28; this may for example be a glass-fibre/rubber composite gasket such as  
30 a Klingersil gasket (trade mark, available from Klinger Ltd. of Bradford, England). The flanges 26 and 28 are clamped together by four bolts 34 which pass through corresponding holes in the flange 28 without touching it, and screw into threaded holes in the flange 26, the head  
35 of the bolt 34 being separated from the flange 28 by a washer 35 and an insulating gasket 36 (only one such bolt

34 is shown). After assembly of both the electrodes 22 to the duct 10, tests are carried out to ensure there is no electrical contact between the two electrodes 22, or between either electrode 22 and the duct 10 (in the absence of liquid metal).

It will be appreciated that the pump 5 may be used with a wide variety of different molten metals. In most cases the metal must be maintained at elevated temperature to remain molten, so the duct 10 will be provided with heating elements (not shown) such as trace heating, and also enclosed with thermal insulation (not shown). It will also be appreciated that a pump may differ from that described above, while remaining within the scope of the invention. For example the duct for liquid metal flow might be of a different shape and size, and might be of a different material such as titanium, or a ceramic material, or (for lower temperature operation) a plastic material. The side ducts enclosing the electrodes might be of a different shape, and might be longer or shorter than shown; at an extreme the side ducts might be only as long as the wall thickness, and the electrode flanges be clamped directly onto the side walls of the flow duct (with interposed gaskets); in this case bolts or studs might be welded to the outside of the duct around the aperture to locate and attach the electrodes. Similarly, the electrodes might be of a different shape, and of a different material, than described above.

When the pump 5 is used to pump used solder (in a molten state) it has been found that an electrically-insulating black layer, believed to be of organic material and originating from the flux and oil present in the solder, is gradually deposited on the protruding parts 30 of the electrodes 22. This can be removed by

mechanical scraping, for example once a week.  
Alternatively the deposition can be prevented by  
replacing the electrodes 22 with electrodes of the same  
shape, but of nickel instead of stainless steel, and in  
5 which the protruding parts 30 are coated with aluminium  
oxide leaving the end face exposed.

In use there is a very slight degree of dissolution  
of nickel from the end face into the molten solder, which  
10 ensures the end face does not become coated with the  
black layer; the rate of dissolution is very much less  
than if uncoated nickel electrodes are used, as with  
uncoated electrodes there is considerably greater  
dissolution at the sides than at the end. In addition  
15 the current is more effectively passed through the  
solder, rather than passing through the wall of the duct,  
so the solder is pumped faster; in tests using a standard  
quantity of molten solder, the times taken to transfer  
the solder using different electrodes 22 were: stainless  
20 steel, 30 to 35 sec; uncoated nickel, 30 sec; coated  
nickel, 18 sec. The aluminium oxide coating may be  
deposited by thermal spraying, and it is desirable to  
first deposit a bonding coat or interlayer to minimize  
the mismatch in thermal expansivity between adjacent  
25 materials. It will be appreciated that the coating may  
be of other electrically-insulating materials, for  
example other ceramic materials.

It may also be beneficial to coat the inner surfaces  
30 of the branch ducts 18 with an insulating coating, for  
example of alumina, to ensure that the electric current  
does not tend to flow into the wall of the duct 10 as the  
end of the electrode 22 gradually dissolves.



Claims

1. A pump for pumping a liquid metal, the pump comprising a duct which in operation contains said liquid  
5 metal, the duct extending through a region in which a magnet creates a magnetic field so the longitudinal axis of the duct is transverse to the magnetic field, two side ducts extending transverse to both the axis of the duct and to the magnetic field, and communicating with  
10 respective apertures at opposite sides of the duct, electrodes locating in the side ducts, demountably connected to them and sealed to them by gaskets, and means to apply an electric voltage between the electrodes, such that the electrodes are electrically  
15 insulated from each other in the absence of the liquid metal.
2. A pump as claimed in Claim 1 wherein the duct is of rectangular cross-section in the vicinity of the magnetic  
20 field, and the side ducts and the electrodes are also of rectangular cross-section
3. A pump as claimed in Claim 1 or Claim 2 wherein the end face of each electrode is substantially flush with  
25 the inner surface of the wall of the duct.
4. A pump as claimed in any any one of the preceding claims wherein the sides of that part of each electrode which locates within one of the side ducts are coated  
30 with an electrically insulating material.
5. A pump as claimed in any one of the preceding claims wherein the sides of that part of each electrode which locates within one of the side ducts are coated with a  
35 ceramic material.

6. A pump as claimed in Claim 5 wherein the coating is of aluminium oxide.

7. A pump as claimed in any one of the preceding claims  
5 wherein the electrodes are of nickel.

8. A pump as claimed in any one of the preceding claims wherein the inner surfaces of the side ducts are coated with an electrically insulating material.

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9. A pump substantially as hereinbefore described with reference to, and as shown in, the accompanying drawings.

10. The use of a pump as claimed in any one of the  
15 preceding claims to pump molten solder.

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Application No: GB 9720098.4  
Claims searched: 1-5

Examiner: John Cockitt  
Date of search: 27 October 1997

**Patents Act 1977**  
**Search Report under Section 17**

**Databases searched:**

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.O): H2A [S4]

Int Cl (Ed.6): H02K [44/04]

Other:

**Documents considered to be relevant:**

Category	Identity of document and relevant passage	Relevant to claims
A	GB0976113A COMMISSARIAT	
A	GB0914908A MINNEAPOLIS	
A	WO97/11521A1 AKZO	
A	US4767953A TANAKA	

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
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&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.